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Pricing PEV Charging: Financial Viability and Fueling Costs

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Plug-in Electric Vehicle Infrastructure Information Gathering Meeting
Sacramento CA

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innovation.luskin.ucla.edu/ev

Outline

- Pricing Workplace Charging
  - Station financial viability
  - Driver fueling costs
- Additional, "parting" thoughts
  - e-miles and battery asset utilization
  - "Path of Least Resistance" blog
  - etc.

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Pricing Workplace Charging: Financial Viability and Fueling Costs

Brett Williams, MPhil (cantab), PhD and JR DeShazo, PhD

Transportation Research Record

(forthcoming, pre-publication manuscript at innovation.luskin.ucla.edu/ev)

Workplace Charging Viability Analysis: Questions

- How much of their station investment can employers expect to recover at prices employee drivers are willing to pay?
- Which pricing structures are most robust to uncertainty?
- Which pricing structures are the most fair to employee drivers?
- What might help improve the cost-recovery potential?

Workplace charging level 2 scenario

Fee structure:	Per-hour, per-kWh, or per-month	**1-way commute (mi):**	15	**Electricity (/kWh):**	$0.1275
Session fee:	$0 or $1	**kWh purchased:**	5.2	**Discount rate:**	5%
Charger (kW):	3.5 ~Level 2	**Utilization (hour/d):**	1.5	**Days/year:**	240

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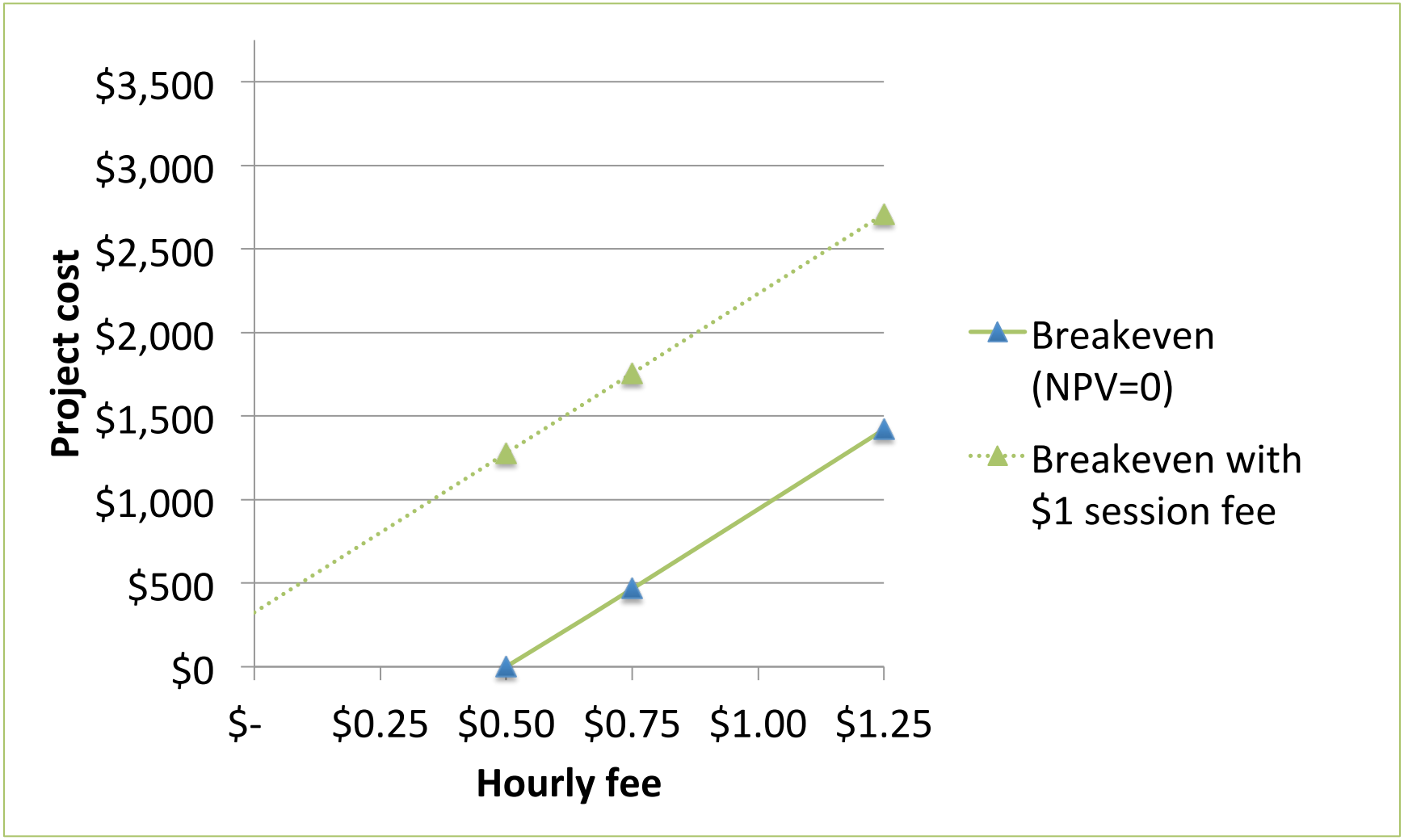
Station cost recovery

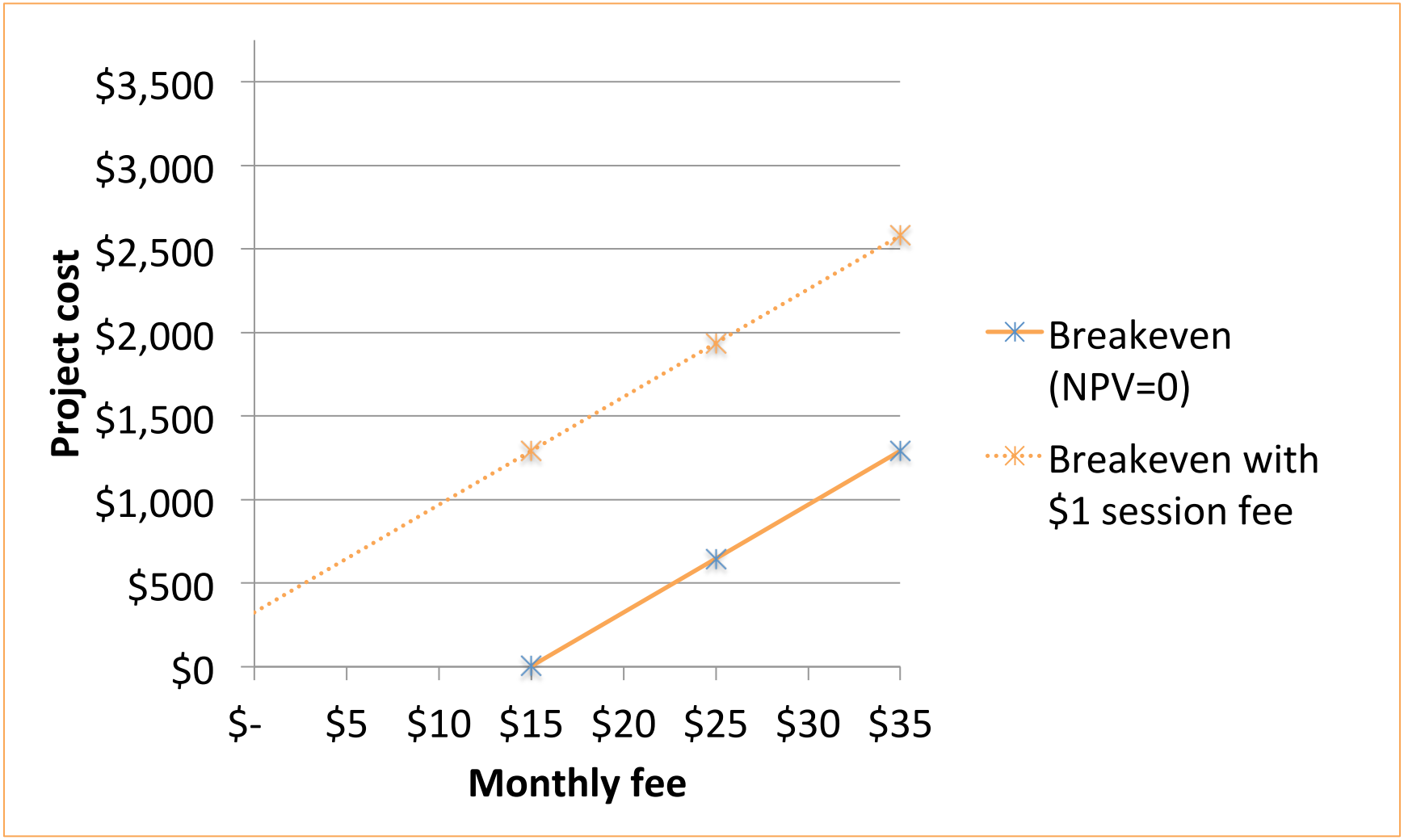
10-year present value of net revenues (NPV)

Workplace charging breakeven pricing: per-hour

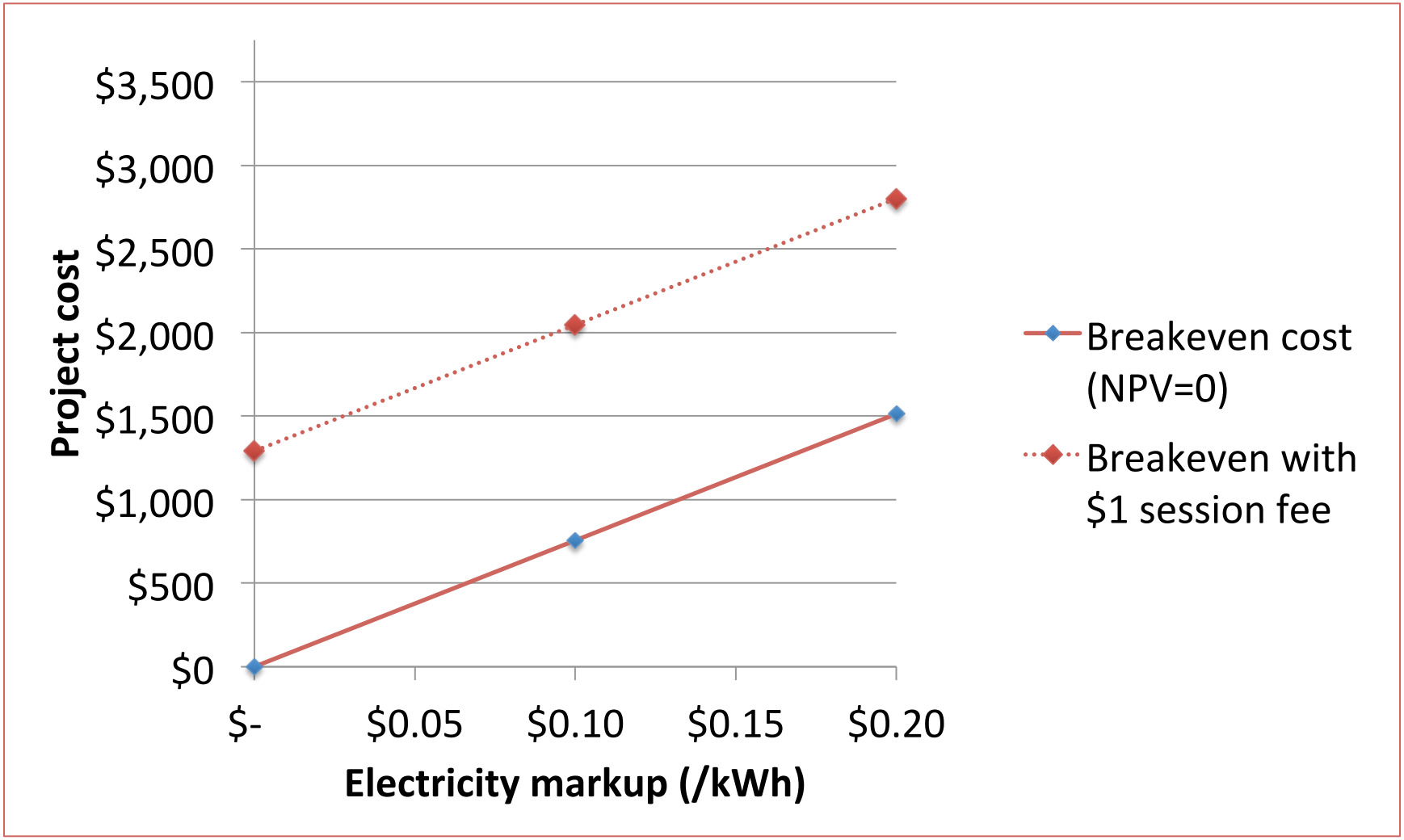
Workplace charging breakeven pricing: per-hour



Workplace charging breakeven pricing: per-month



Workplace charging breakeven pricing: per-kWh



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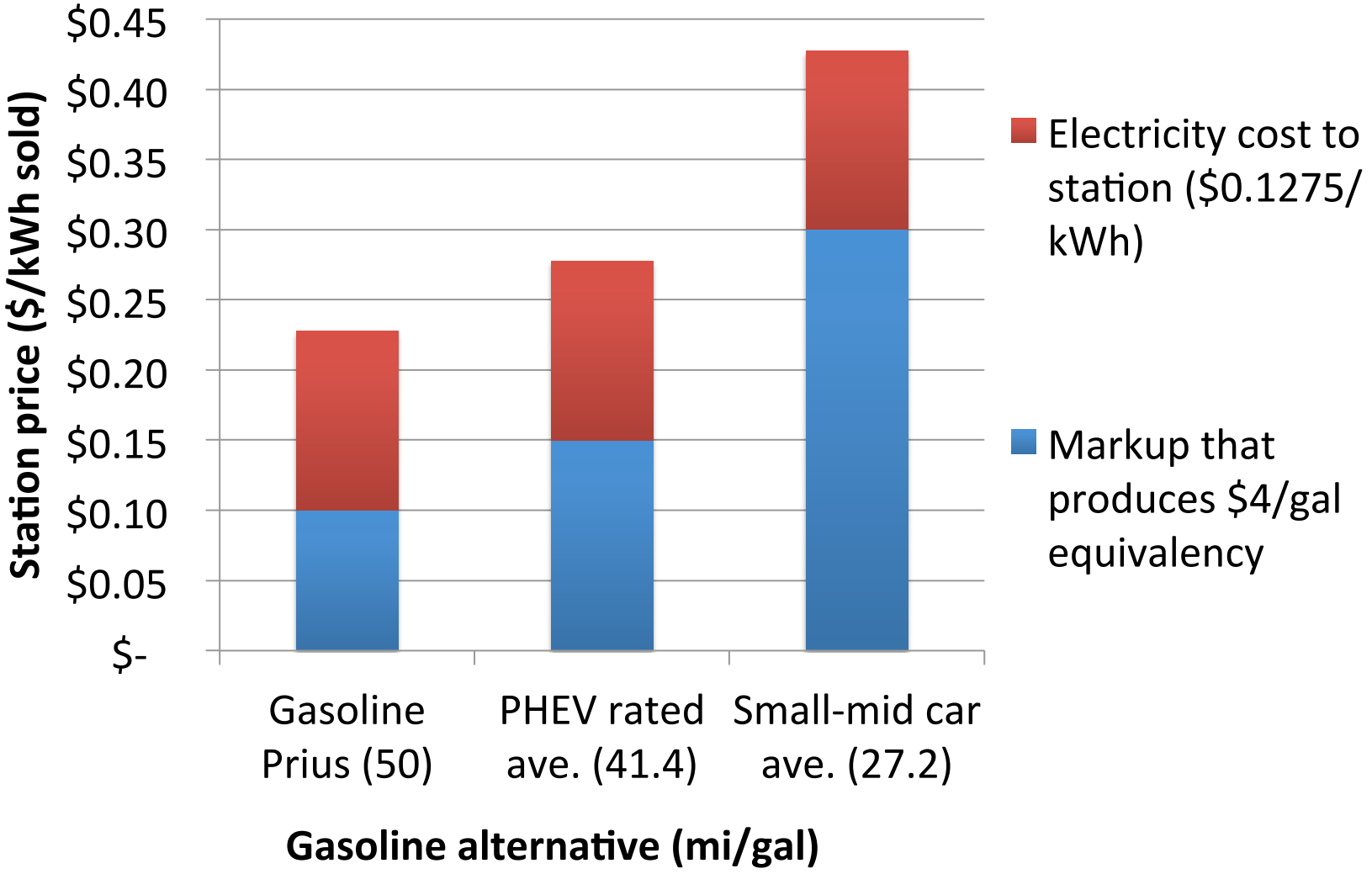
What is the most a "rational" driver would pay for electric fuel?

(on average, over time)

$4/gallon of gasoline equivalents



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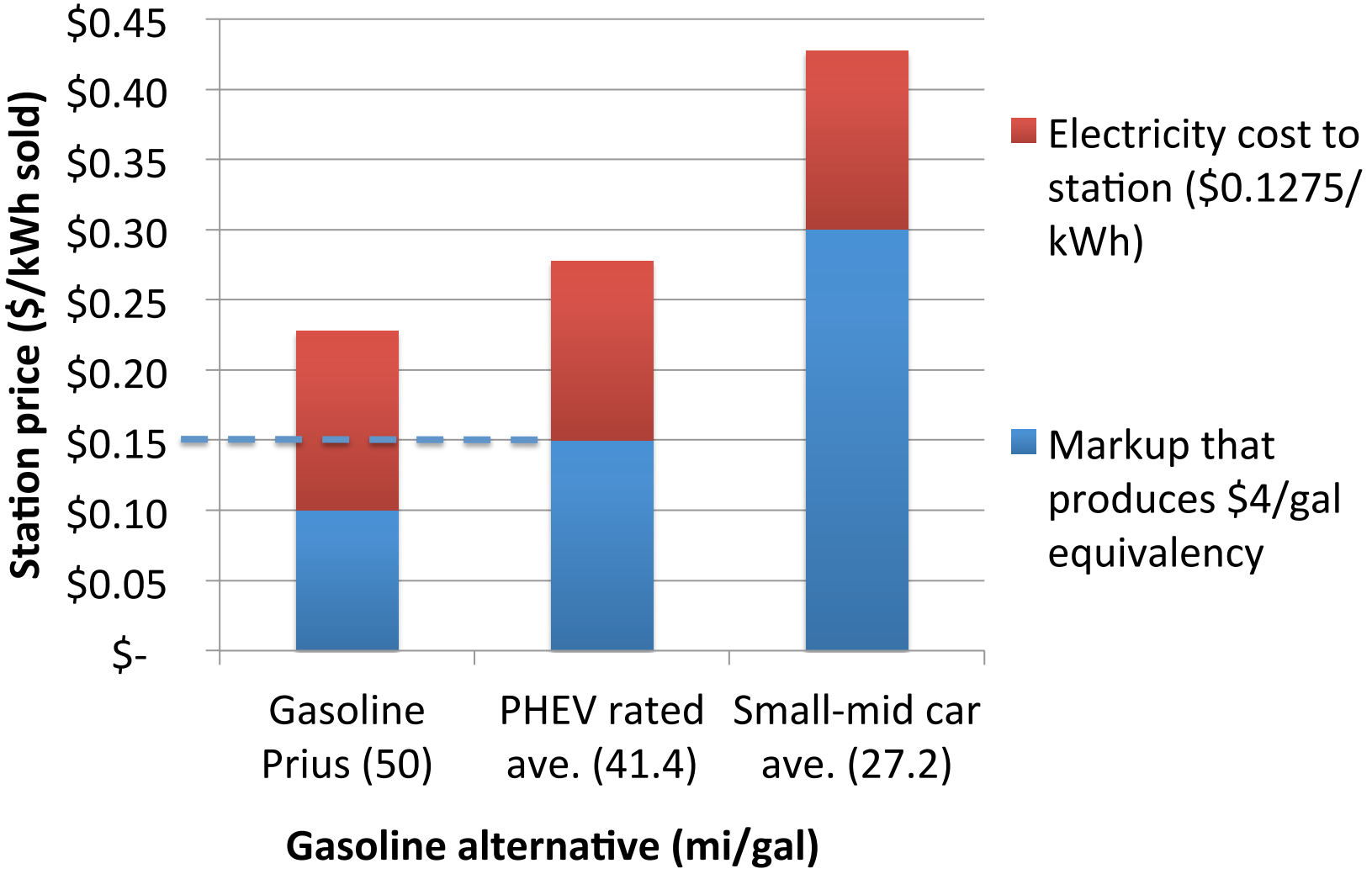
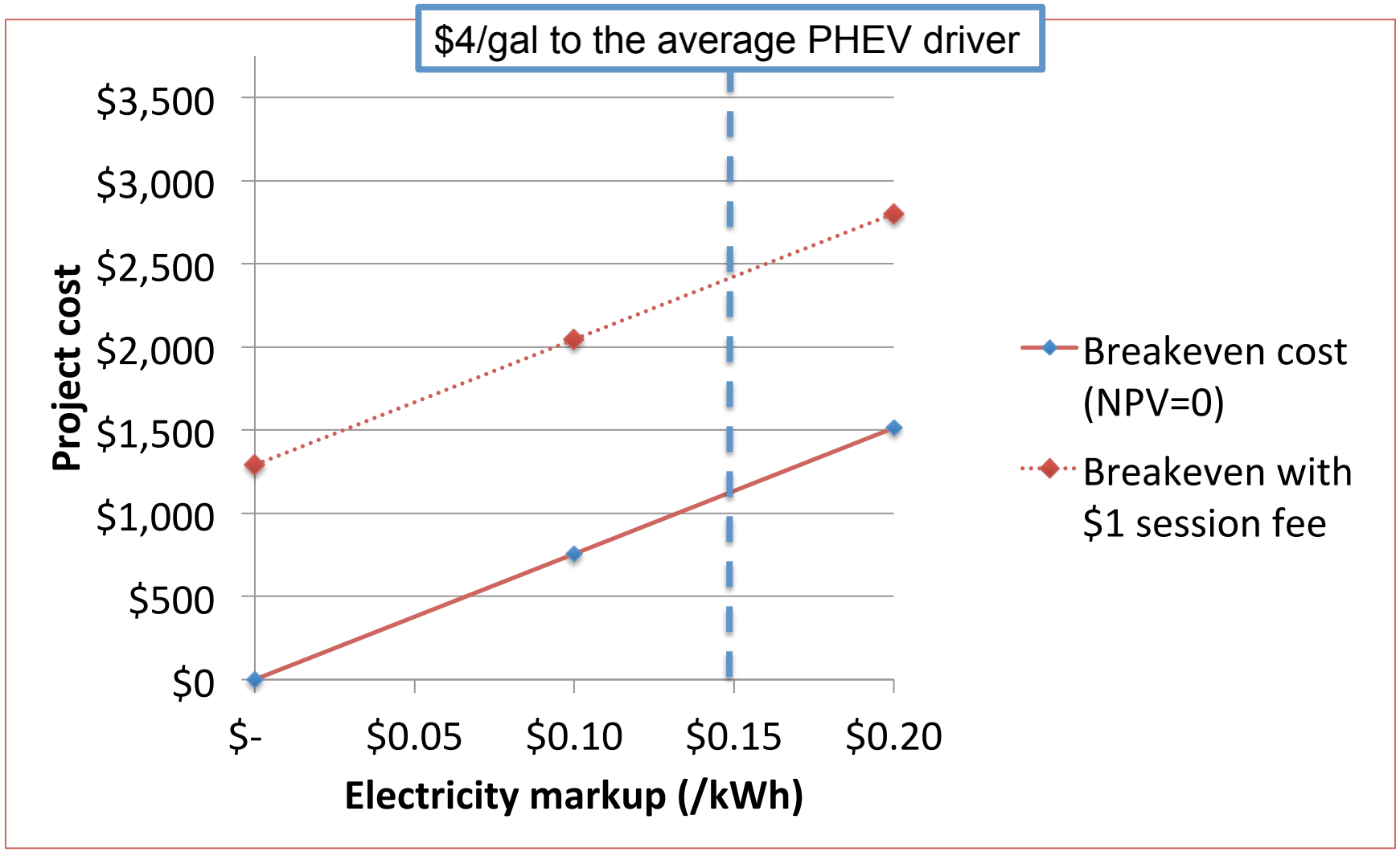
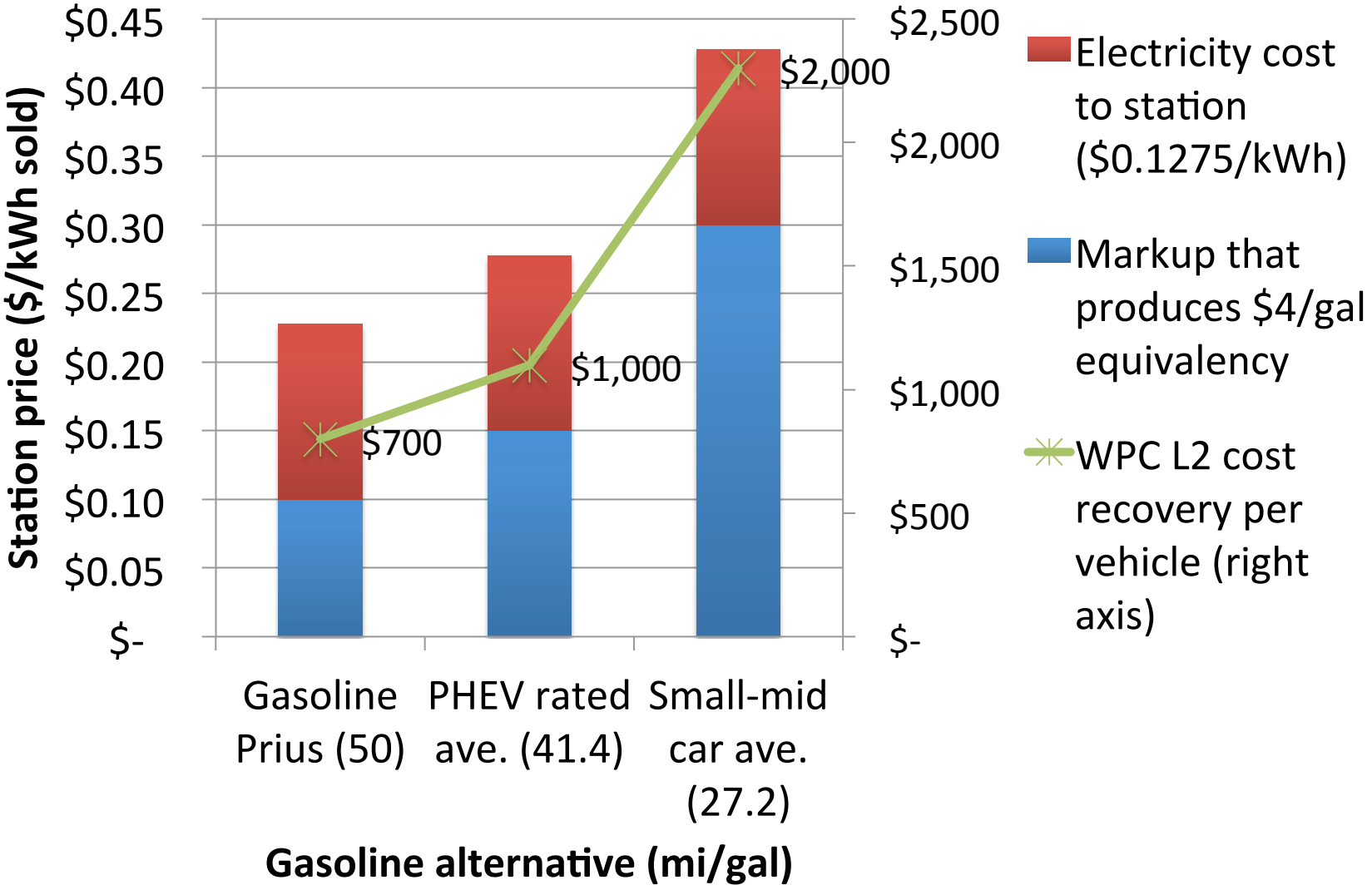


Workplace charging breakeven pricing: per-kWh



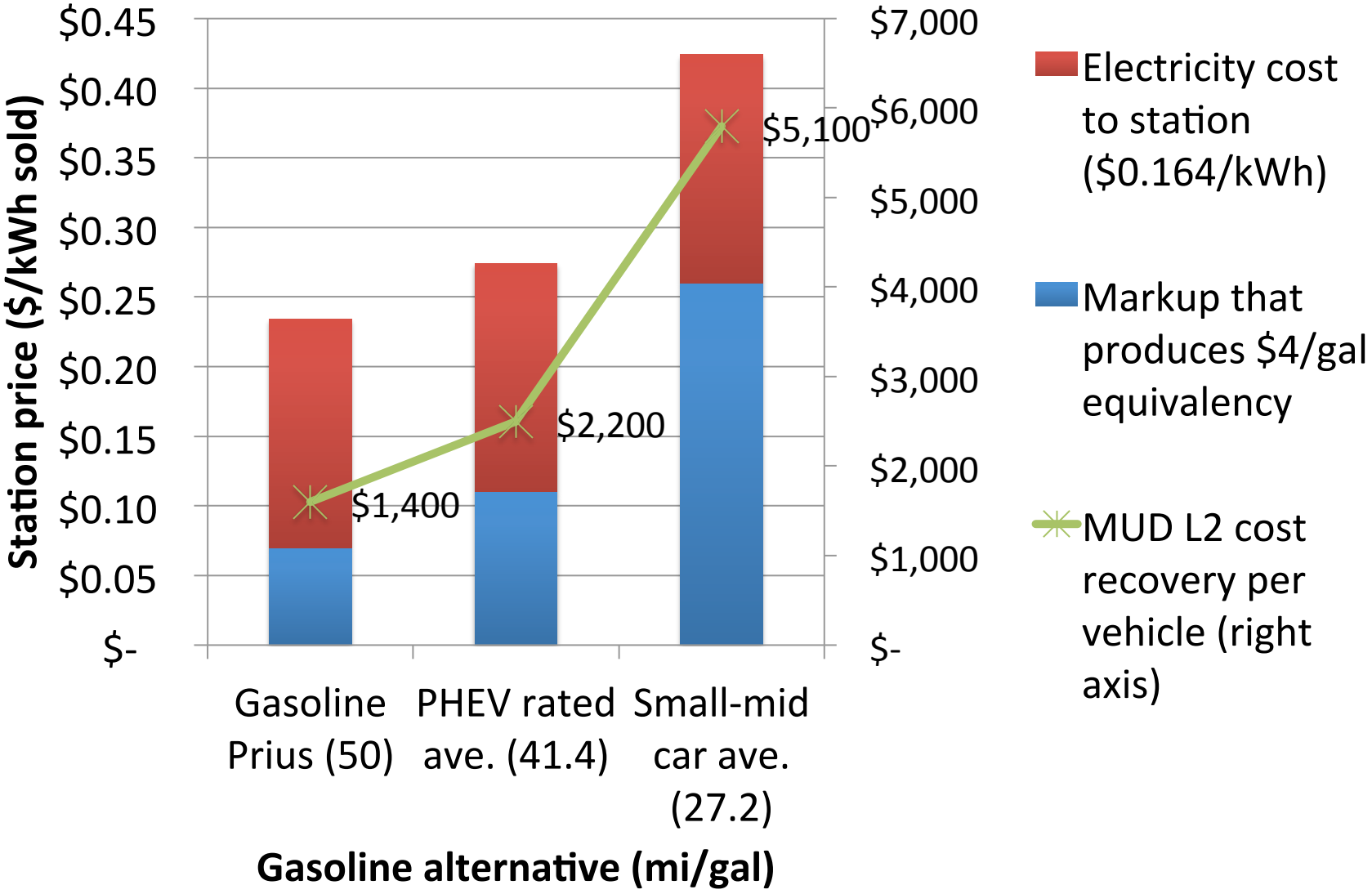
What is the cost recovery potential, given the "most" a given type of driver is willing to pay?



MUD charging level 2 scenario

Fee structure:	Per-hour, per-kWh, or per-month	**Ave. daily driving (mi):**	30	**Electricity (/kWh):**	$0.164
Session fee:	$0	**kWh purchased:**	10.5	**Discount rate:**	5%
Charger (kW):	3.5 (Level 2)	**Utilization (hour/d):**	3.0	**Days/year:**	350

What is the MUD cost recovery potential, given the "most" a given type of driver is willing to pay?



Monte Carlo uncertainty analysis: Inputs

Input parameter	*Min.*	***Best guess***	*Max.*
One-way commute distance (mi)	10	**15**	20
Maintenance costs (% of all-in costs)	1%	**5%**	10%
Discount rate	3%	**5%**	10%
PEV electric fuel economy (kWh/100mi)	30.1	**34.5**	38
Escalation of markup	1%	**3%**	5%
Commute days per year	235	**240**	260
Maintenance cost escalation	**1%**	**uniform (3%)**	**5%**
Charging power (kW)	1.4	**3.5**	7.2
Electricity cost (/kWh)	$0.0901	**$0.1275**	$0.30
Electricity cost escalation	1%	**3%**	12%

Workplace-charging case

Monte Carlo uncertainty analysis: Importance

	+$0.30/kWh	$1.50/hour	$45/month
Point estimate	$386	($148)	($91)
Monte Carlo mean	$264	($1,387)	($910)
95% confidence interval	($829) to $1,460	($3,426) to $2,517	($2,535) to $300

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95% confidence interval	($829) to $1,460	($3,426) to $2,517	($2,535) to $300
Input parameter	***Uncertainty Contribution[a]***		
One-way commute distance (mi)	54%	2%	-14%
Maintenance costs (% of all-in costs)	-27%	-6%	-19%
Discount rate	-8%		-1%
PEV electric fuel economy (kWh/100mi)	6%	0.2%	2%
Escalation of markup	3%		
Commute days per year	1%	0.1%	-0.3%
Maintenance cost escalation	-1%	-0.2%	-0.3%
Charging power (kW)		-73%	
Electricity cost (/kWh)		-16%	-56%
Electricity cost escalation		2%	-7%

[a] Described in the text, this is a metric based on normalized rank correlation coefficients

How can we make this better?

a) **Fee structure** per-kWh **Session fee** $0.00

Electricity markup

Project Cost	$ -	$ 0.10	$ 0.20	$ 0.30
$ -	$ -	$ 1,087	$ 2,174	$ 3,261
$ 1,000	$ (1,437)	$ (350)	$ 737	$ 1,824
$ 2,000	$ (2,875)	$ (1,788)	$ (701)	$ 386
$ 3,000	$ (4,312)	$ (3,225)	$ (2,138)	$ (1,051)
$ 4,000	$ (5,750)	$ (4,662)	$ (3,575)	$ (2,488)
$ 5,000	$ (7,187)	$ (6,100)	$ (5,013)	$ (3,926)
$ 6,000	$ (8,624)	$ (7,537)	$ (6,450)	$ (5,363)
$ 7,000	$ (10,062)	$ (8,975)	$ (7,887)	$ (6,800)
$ 8,000	$ (11,499)	$ (10,412)	$ (9,325)	$ (8,238)

c) **Fee structure** per-hour **Session fee** $0.00

Hourly fee

Project cost	$ 0.50	$ 0.75	$ 1.25	$ 1.50
$ -	$ (15)	$ 670	$ 2,041	$ 2,727
$ 1,000	$ (1,453)	$ (767)	$ 604	$ 1,289
$ 2,000	$ (2,890)	$ (2,205)	$ (834)	$ (148)
$ 3,000	$ (4,327)	$ (3,642)	$ (2,271)	$ (1,586)
$ 4,000	$ (5,765)	$ (5,079)	$ (3,708)	$ (3,023)
$ 5,000	$ (7,202)	$ (6,517)	$ (5,146)	$ (4,460)
$ 6,000	$ (8,639)	$ (7,954)	$ (6,583)	$ (5,898)
$ 7,000	$ (10,077)	$ (9,391)	$ (8,021)	$ (7,335)
$ 8,000	$ (11,514)	$ (10,829)	$ (9,458)	$ (8,773)

e) **Fee structure** per-month **Electricity fee** $0.00

Monthly fee

Project cost	$ 15	$ 25	$ 35	$ 45
$ -	$ 4	$ 930	$ 1,857	$ 2,784
$ 1,000	$ (1,433)	$ (507)	$ 420	$ 1,346
$ 2,000	$ (2,871)	$ (1,944)	$ (1,018)	$ (91)
$ 3,000	$ (4,308)	$ (3,382)	$ (2,455)	$ (1,528)
$ 4,000	$ (5,746)	$ (4,819)	$ (3,892)	$ (2,966)
$ 5,000	$ (7,183)	$ (6,256)	$ (5,330)	$ (4,403)
$ 6,000	$ (8,620)	$ (7,694)	$ (6,767)	$ (5,841)
$ 7,000	$ (10,058)	$ (9,131)	$ (8,205)	$ (7,278)
$ 8,000	$ (11,495)	$ (10,569)	$ (9,642)	$ (8,715)

Increasing utilization

a) Fee structure: per-kWh; Session fee: $0.00

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a) **$0.30/kWh markup**

Utilization per day

Project cost	1 PEV 15 e-mi 5.2 kWh	2 PEVs 30 e-mi 10.4 kWh	3 PEVs 45 e-mi 15.5 kWh	4 PEVs 60 e-mi 20.7 kWh
$ -	$ 3,261	$ 6,522	$ 9,784	$ 13,045
$ [illegible]	$ 1,824	$ 5,085	$ 8,346	$ 11,608
$ 2,000	$ 386	$ 3,648	$ 6,909	$ 10,170
$ 3,000	$ (1,051)	$ 2,210	$ 5,472	$ 8,733
$ 4,000	$ (2,488)	$ 773	$ 4,034	$ 7,295
$ 5,000	$ (3,926)	$ (664)	$ 2,597	$ 5,858
$ 6,000	$ (5,363)	$ (2,102)	$ 1,159	$ 4,421
$ 7,000	$ (6,800)	$ (3,539)	$ (278)	$ 2,983
$ 8,000	$ (8,238)	$ (4,977)	$ (1,715)	$ 1,546
$ 9,000	$ (9,675)	$ (6,414)	$ (3,153)	$ 109
$ 10,000	$ (11,113)	$ (7,851)	$ (4,590)	$ (1,329)

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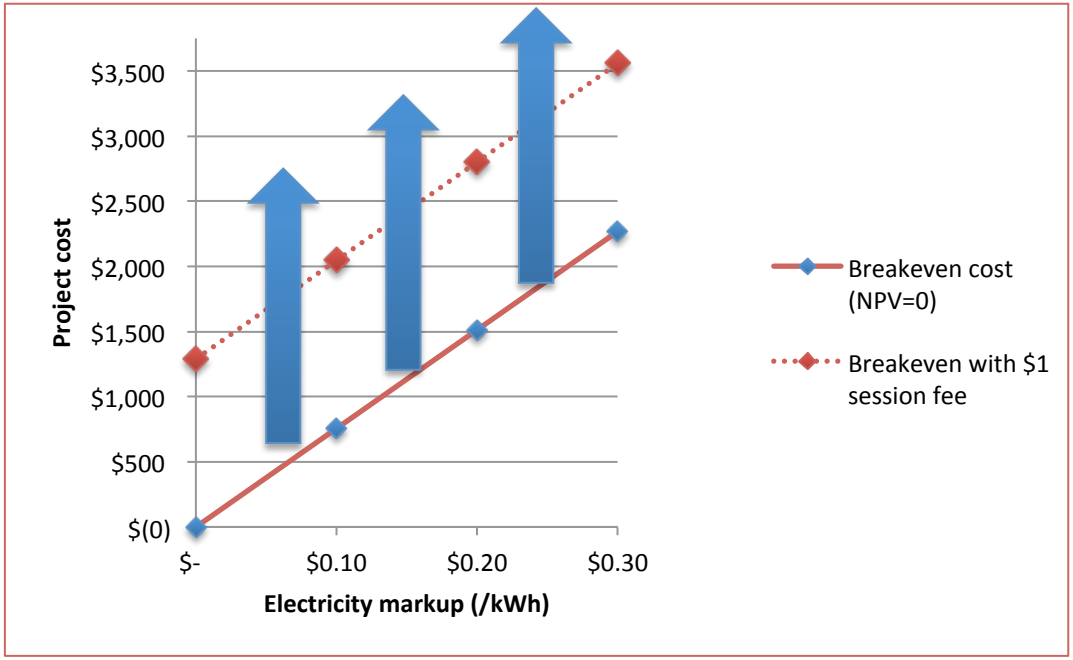
- Challenges:
  - Productivity losses and/or other costs of shuffling cars
  - Afternoon energy and demand peaks
- Multiplexing/low-power charging:
  - Route the available power to the cars, not the cars to the available power

Supplemental Value?

- Might secondary use of charging facilities help?
  - Employee + fleet + nighttime public access?
  - Smart charging to provide grid-support services



Summary (in round numbers)

- If $4/gal equivalent is an important threshold, this allows for:
  - station prices of less than $0.30/kWh
- Workplace ($0.15/kWh of total is markup): covers only ~$1,000 in all-in facility costs per PEV
  - $1/hour or $30/month do too
- Per-kWh pricing
  - potentially more robust to uncertainty, with better upside potential
  - less unintentional price discrimination
- Strategies to lower costs and improve station value:
  - "Simple" solutions
  - multiplexing, low-power, fleet and/or public access, grid-support services

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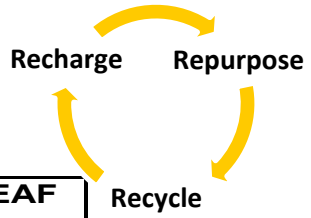
Additional, "parting" thoughts…

Battery second-life revenue from grid-support services

(Williams & Lipman 2011)



Application	PHV	Volt	LEAF
Electric Energy Time-shift	$330	$880	$1,720
Electric Supply Capacity	$320	$850	$1,670
Load Following	$800	$2,130	$4,180
Area Regulation	$8,720	$23,250	$45,610
Electric Supply Reserve Capacity	$280	$750	$1,470
Voltage Support	$2,870	$7,670	$15,040
Transmission Support	$1,200	$3,190	$6,270
Transmission Congestion Relief	$60	$150	$300
T&D Upgrade Deferral 50th percentile†	$2,390	$6,470	$12,490
T&D Upgrade Deferral 90th percentile†	$3,760	$10,020	$19,660
Substation On-site Power	$600	$1,600	$3,130
Time-of-use Energy Cost Management	$730	$1,960	$3,840
Demand Charge Management	$220	$580	$1,140
Electric Service Reliability	$3,700	$9,860	$19,340
Electric Service Power Quality	$4,170	$11,120	$21,820
Renewables Energy Time-shift	$230	$620	$1,220
Renewables Capacity Firming	$810	$2,160	$4,240
Wind Generation Grid Integration, Short Duration	$4,680	$12,480	$24,480
Wind Generation Grid Integration, Long Duration	$380	$1,000	$1,970

* lifecycle benefit over 10 years, with 2.5% escalation and 10% discount rate

† converted here to approximate 10 years of benefit to be comparable to other applications, but this is not likely at a single location

Supplemental Value?

- Given the limited cost-recovery potential of workplace charging, some employers may want additional value
- Might secondary use of charging facilities help?
  - Employee + fleet + nighttime public access?
  - Control (and aggregation) of recharging timing and rate (i.e., smart charging) to provide grid-support services

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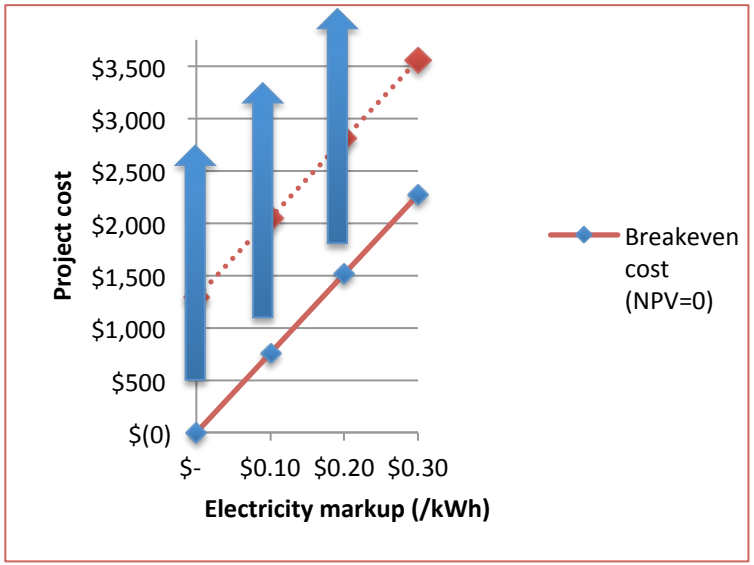
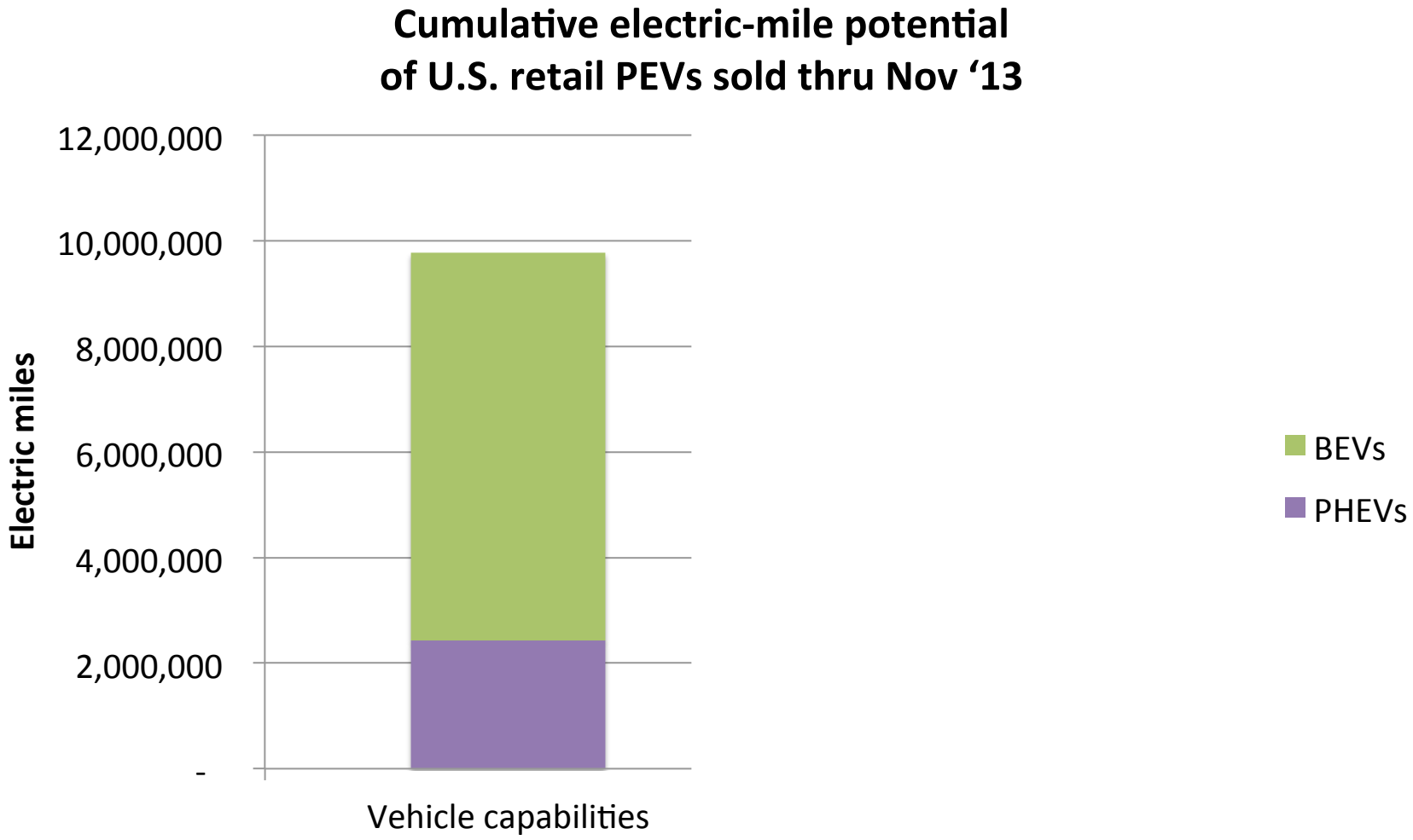
Grid-support revenue streams



?

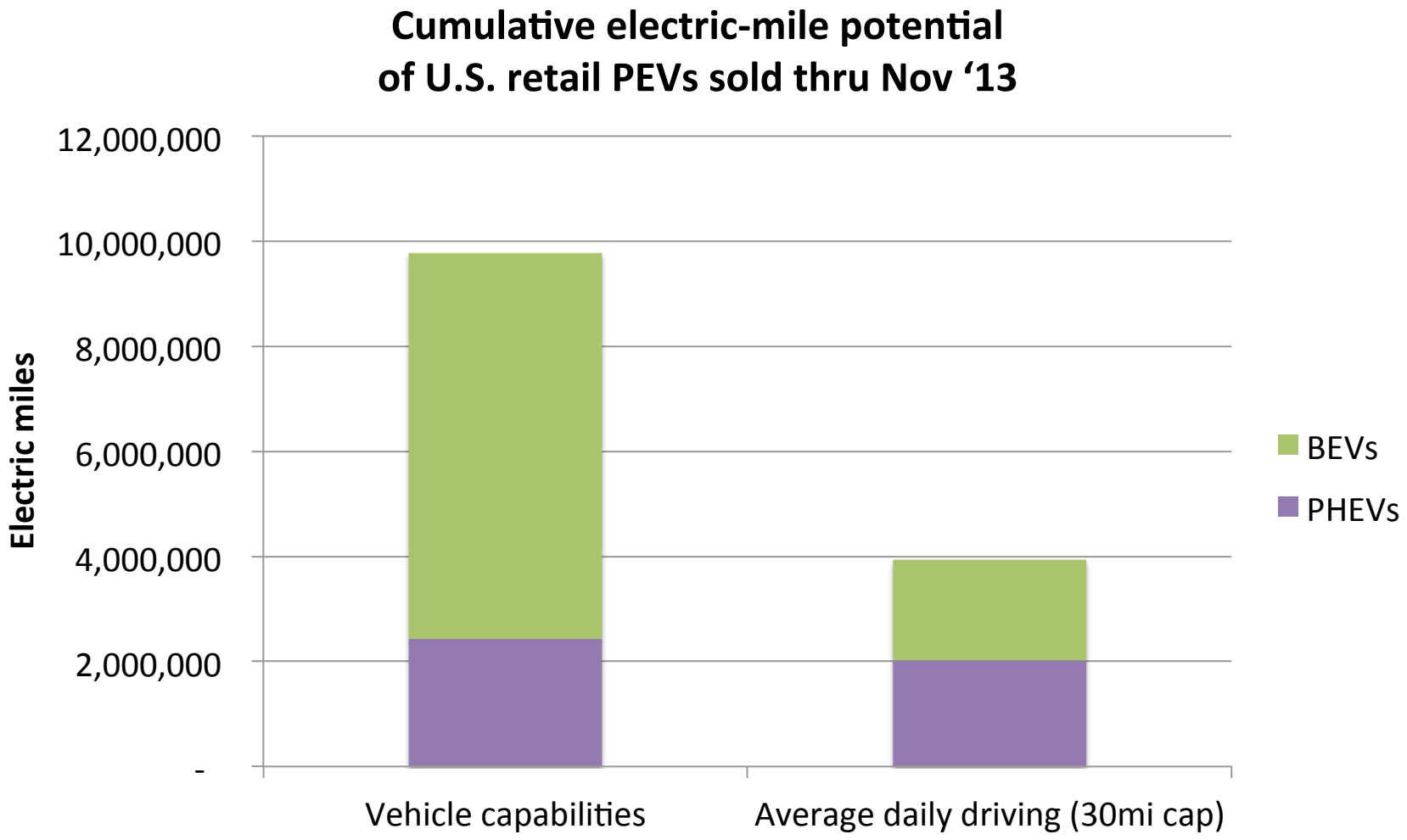
Does size matter?
Per-charge and per-day e-mile potential

(Williams 2013)



Does size matter?
Per-charge and per-day e-mile potential

(Williams 2013)



Illustrative e-mile cost effectiveness (assuming $500 per rated kWh across the board)

Model		Battery cost/e-mi range
LEAF MY'11	BEV	$163
Chevy Volt	PHEV	$217
smart fortwo ed MY'11	BEV	$131
i	BEV	$129
Focus Electric	BEV	$151
Active E	BEV	$170
Prius Plug-In	PHEV	$200
Model S 85kWh	BEV	$160
Fit EV	BEV	$122
RAV4EV	BEV	$203
C-Max Energi	PHEV	$181
Model S 60kWh	BEV	$144
Accord Plug-in	PHEV	$258
Fusion Energi	PHEV	$181
LEAF S MY'13	BEV	$158
smart electric drive MY'13	BEV	$129
Chevy Spark	BEV	$128
500 Elettrica	BEV	$138

(Williams 2013)

Illustrative e-mile cost effectiveness (assuming $500 per rated kWh across the board)

Model		Battery cost/e-mi range	Battery cost/e-mi daily driving
LEAF MY'11	BEV	$163	$396
Chevy Volt	PHEV	$217	$275
smart fortwo ed MY'11	BEV	$131	$275
i	BEV	$129	$267
Focus Electric	BEV	$151	$383
Active E	BEV	$170	$533
Prius Plug-In	PHEV	$200	$200
Model S 85kWh	BEV	$160	$1,417
Fit EV	BEV	$122	$333
RAV4EV	BEV	$203	$697
C-Max Energi	PHEV	$181	$181
Model S 60kWh	BEV	$144	$1,000
Accord Plug-in	PHEV	$258	$258
Fusion Energi	PHEV	$181	$181
LEAF S MY'13	BEV	$158	$396
smart electric drive MY'13	BEV	$129	$293
Chevy Spark	BEV	$128	$350
500 Elettrica	BEV	$138	$400

(Williams 2013)

“Path of Least Resistance”

http://luskin.ucla.edu/blogs/brettwilliams

UCLA Luskin School *of* Public Affairs

Luskin Center for Innovation

Thank you for your attention!

Additional slides, references available…

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Cost of fueling

Table 3-7: Illustrative fueling cost benchmarks: Per-hour workplace charging

Pricing Level	$ per electric mile	Electricity equivalent	Gasoline equivalent (CV)	Gasoline equivalent (PHEV)
H1. $0.50/hour actively charging	$0.05/e-mi	$0.14/kWh	$1.34/gal	$2.02/gal
H2. $0.75/hour actively charging	$0.07/e-mi	$0.21/kWh	$2.01/gal	$3.03/gal
H3. $1.25/hour actively charging	$0.12/e-mi	$0.36/kWh	$3.35/gal	$5.05/gal

Fueling Cost Benchmarks: WPC vs. Gasoline

Pricing Level	$ per electric mile	Electricity equivalent	Gasoline equiv. (Ave. vehicle)	Gasoline equivalent (PHEV or hybrid)
1. breakeven prices			*"A Steal"*	*"Incentivizing"*
Electricity cost=$0.1275/kWh (in year 1)	$0.04/e-mi	*$0.13/kWh*	$1.20/gal	$1.80
$0.50/hour actively charging	$0.05/e-mi	$0.14/kWh	$1.34/gal	$2.02
$15/month	$0.05/e-mi	$0.14/kWh	$1.36/gal	$2.05
2. low prices			*"Incentivizing"*	*"Cheap"*
$0.75/hour actively charging	$0.07/e-mi	$0.21/kWh	$2.01/gal	$3.03
Electricity cost + $0.10/kWh	$0.08/e-mi	*$0.23/kWh*	$2.14/gal	$3.22
$25/month	$0.08/e-mi	$0.24/kWh	$2.27/gal	$3.42
3. medium prices			*"Cheap"*	*"Uncompetitive"*
Electricity cost + $0.20/kWh	$0.11/e-mi	*$0.33/kWh*	$3.08/gal	$4.64
$35/month	$0.12/e-mi	$0.34/kWh	$3.17/gal	$4.78
$1.25/hour actively charging	$0.12/e-mi	$0.36/kWh	$3.35/gal	$5.05
Low gasoline price	$0.13/e-mi	$0.37/kWh	*$3.50/gal*	
Gasoline price (~CA 2012 average)	$0.15/e-mi	$0.43/kWh	*$4.00/gal*[a]	